REFLECTANCE SPECTRA OF UREILITES: NATURE OF THE MAFIC SILICATE ABSORPTION FEATURES.
E.A. Cloutis[1] and P. Hudon[2], [1]University of Winnipeg, Department of Geography, 515 Portage Ave., Winnipeg, MB, Canada; e.cloutis@uwinnipeg.ca, [2]Astromaterials Research and Exploration Science Office, NASA Johnson Space Center, Mail Code SR, 2101 NASA Road 1, Houston, Texas, USA, pierre.hudon1@jsc.nasa.gov.

Introduction: Ureilites are unique carbon-bearing achondrites. They are composed primarily of olivine and pyroxene with minor amounts of finely dispersed matrix material consisting mostly of carbon, metal, sulfides and fine-grained silicates [1,2]. As is the case with many classes of meteorites, no clear chain of evidence exists which can relate them to specific asteroidal parent bodies. In order to provide insights into parent body connections, visible and near-IR (VNIR) reflectance spectra of a number of ureilites have been measured and analyzed in light of their mineralogy.

Experimental Procedure: A total of 12 ureilites have been spectrally characterized. Their mafic silicate mineralogy is given in Table 1. VNIR diffuse reflectance spectra were obtained at room temperature using the instrument and methods described by [3].

Table 1. Mafic silicate mineralogy of ureilites investigated

Ureilite	Mineralogy (modal %)	Ref.
GRA 95205	ol(94)+pig(5)	[4]
GRO 95575	ol(90)+pig(9)	[4]
ALH 77257	ol(80)+pig(15)	[5]
Novo-Urei	ol(77)+pig(22)	[4]
Goalpara	ol(77)+pig(23)	[6]
PCA 82506	ol(52)+pig(48)	[7]
ALH 81101	ol+pig	[8]
EET 96042	ol+pig	[8]
EET 87517	ol(45)+opx(55)	[4,8]
Y 791538	ol(55)+pig(27)+opx(18)	[9]
ALH 82130	ol(40)+pig(40)+aug(10)	[10]
	ol(60)+pig+aug(total px:30)	[11]
LEW 88201	ol(46)+pig(54)+aug(rare)	[12]
META 78008	ol(63)+aug(30)+opx(4)+ pig(3)	[13]

Results: The reflectance spectra of the various ureilites (Figure 1) show a number of common features, specifically low overall reflectance (generally less than 25%) a reflectance maximum near 0.7 microns, and a broad, but weak, absorption feature in the 1 micron region. Reflectance is generally flat or slightly decreasing beyond about 1.2 microns.

Detailed analysis of the broad absorption feature in the 1-micron region shows evidence for two partially overlapping absorption bands. These bands generally appear near 0.92 and 1.02 microns, with variations in band positions between different samples.

Discussion: On the basis of the inferred mineralogies of the ureilites (largely olivine and subordinate pigeonite or, less frequently augite or orthopyroxene), the absorption band positions appear in the approximate locations expected from their mafic silicate mineralogies. However, importance differences exist between the ureilite spectra and the spectra of mafic silicate mixtures.

The absorption bands found in the ureilite spectra have band depths on the order of 0-12%. This is much less than the equivalent band depths for opaque-free mafic silicates, even for particle sizes <45 microns [14], which are generally on the order of a few tens of percent. The major difference between the ureilites and mafic silicate mixture spectra is that the ureilites contain a few percent of finely dispersed insoluble carbon-rich material [1,2]. Previous laboratory work on the reflectance spectra of mafic silicate + opaque assemblages has shown that the presence of even a few tenths percent finely dispersed opaques can reduce band depths to the levels seen in the ureilites [15].

The ureilite spectra also show much narrower absorption features than corresponding mafic silicate spectra [14]. This is attributable to the presence of the carbon-rich material which leads to an enhancement of surface over volume scattering, accounting for the narrower than expected absorption band widths (as well as the reduced absorption band depths) [14].

In terms of the relative strengths of the pyroxene and olivine absorption bands, based on the available compositional data for the ureilites [4-13], pyroxene absorption bands are of approximately equal intensity to the olivine bands even when the pyroxene-pigeonite abundance is as low as a few percent. There are a number of possible explanations for this. One is that the normative mineralogies for these meteorites may not be representative of the actual samples which were spectrally characterized; pyroxene abundances may be higher or lower than the values stated in the literature. However, if we assume that the normative mineralogies are roughly representative of the samples used in this study, only a few percent pyroxene are required to result in an absorption band of comparable strength to the olivine absorption band. This is due to the fact that pyroxene is a more intense absorber than olivine [14].

The relatively flat slopes of the ureilite spectra are consistent with only certain types of opaque phases. In terms of plausible opaque and/or carbon-rich materials, coal tar extract, bitumen, cementite, wustite, and amorphous carbon mixed with olivine result in reflectance spectra that are more red-sloped than the ureilite spectra. Only diamond and graphite result in neutral or slightly blue-sloped spectra similar to the ureilites. Of these, diamond does not appreciably reduce overall reflectance or dramatically reduce mafic silicate band depths. Consequently, graphite (both crystalline and poorly ordered) is the best opaque candidate; it is also consistent with the opaque material found in the ureilites [1,2].

Spectrally, the ureilites are most similar to certain carbonaceous chondrite meteorite classes and C-class asteroids: all three exhibit low overall reflectance and relatively flat spectral slopes. However, carbonaceous chondrites and C-class asteroid spectra are generally featureless in the 1 micron region, and do not generally exhibit resolvable absorption bands in this region. As a result, C-class asteroids are normally associated with carbonaceous chondrites, although spectral differences do exist between the meteorite and asteroid spectra. If ureilites are to be related to C-class asteroids, the differences between the ureilite and asteroid spectra must be explained. A number of mechanisms could be invoked to account for the spectral differences, such as suppression of the mafic silicate absorption bands due to coating of the mafic silicate grains through asteroid spectral databases to search for spectral features which micrometeorite impacts, or other "space weathering" mechanisms. We are currently searching the available are consistent with the ureilite spectra.

In summary, the ureilite reflectance spectra exhibit absorption features, which are broadly consistent with their mineralogies. The mafic silicate absorption bands are modified in the way expected due to the presence of a fine-grained, intimately dispersed, spectrally neutral opaque phase.

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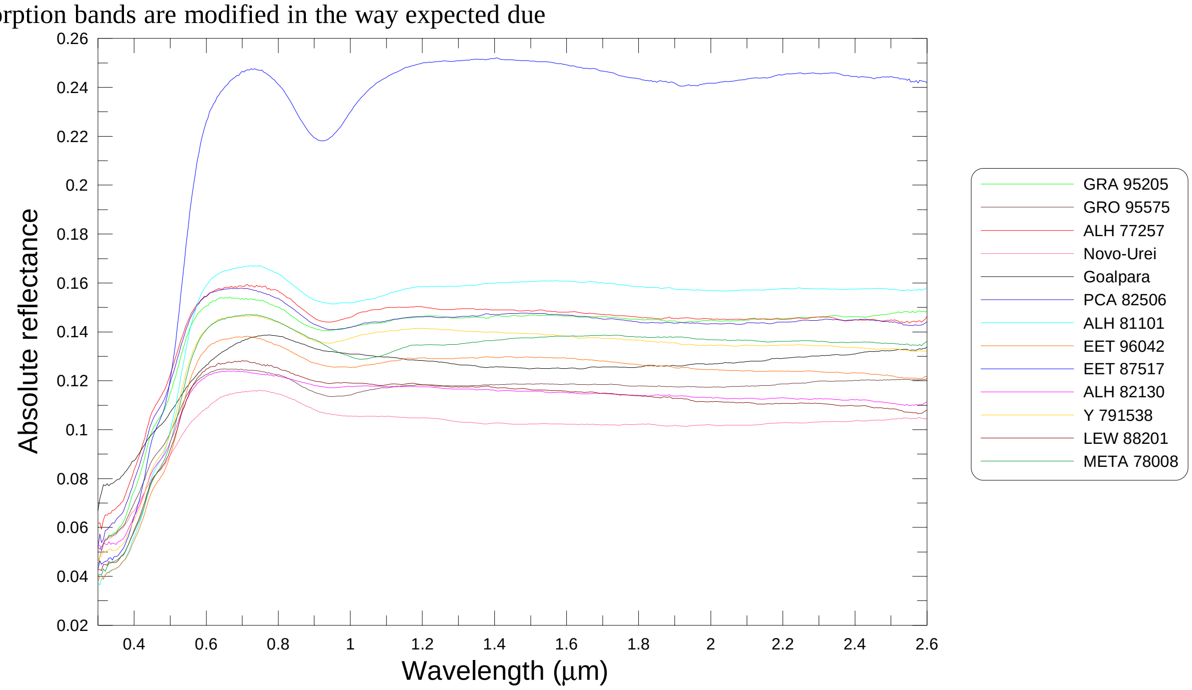

Figure 1.Reflectance spectra of ureilites.